

Three Years of Fermi LAT Flare Advocate Activity

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The Fermi Flare Advocate (also known as Gamma-ray Sky Watcher, FA-GSW) service provides for a daily quicklook analysis and review of the high-energy gamma-ray sky seen by the Fermi Gamma-ray Space Telescope. The duty offers alerts for potentially new gamma-ray sources, interesting transients and relevant flares. A public weekly digest containing the main highlights about the GeV gamma-ray sky is published in the web-based Fermi Sky Blog. During the first 3 years of all-sky survey, more than 150 Astronomical Telegrams, several alerts to the TeV Cherenkov telescopes, and targets of opportunity to Swift and other observatories have been distributed. This increased the rate of simultaneous multi-frequency observing campaigns and the level of international cooperation. Many gamma-ray flares from blazars (like the extraordinary outbursts of 3C 454.3, intense flares of PKS 1510-089, 4C 21.35, PKS 1830-211, AO 0235+164, PKS 1502+106, 3C 279, 3C 273, PKS 1622-253), short/long flux duty cycles, unidentified transients near the Galactic plane (like J0910-5041, J0109+6134, the Galactic center region), flares associated to Galactic sources (like the Crab nebula, the nova V407 Cyg, the microquasar Cyg X-3), emission of the quiet and active sun, were observed by Fermi and communicated by FA-GSWs.

1. Introduction and scope of the FA-GSW service

The Large Area Telescope (LAT), on board the *Fermi* Gamma-ray Space Telescope Atwood et al. [2009], is a pair-conversion γ -ray telescope, sensitive to photon energies from about 20 MeV up to > 300 GeV. The LAT consists of a tracker (two sections, front and back), a calorimeter and an anti-coincidence system to reject the charged-particle background. *Fermi* LAT, working in all-sky survey mode, is an optimal hunter for high-energy flares, transients and new gamma-ray sources, and is an unprecedented monitor of the variable γ -ray sky, thanks to the large peak effective area, wide field of view (≈ 2.4 sr), improved angular resolution and sensitivity.

This all-sky monitoring is complemented by the Flare Advocate (a.k.a. Gamma-ray Sky Watcher, FA-GSW) duty, a scientific service belonging to the LAT Instrument Science Operations and devoted to quicklook inspection and daily review of the gamma-ray sky observed by *Fermi* LAT, performed with continuity for all the year through weekly shifts.

The FA-GSW service points out basic facts and information about the γ -ray sky of potential interest for the LAT internal science groups, through a day-by-day inspection and review of the all-sky photon count maps collected and of the quicklook science pipeline results. Summaries about the sky surveyed



Figure 1: The public weekly Fermi Sky Blog (web address: fermisky.blogspot.com). ATels posted and other information about the day by day γ -ray sources detected above 100 MeV are summarized every week in this web digest.

and monitored by *Fermi* LAT, transients, flaring and new sources on six-hour and 1-day time intervals are communicated along with any relevant news to the external multiwavelength (MW) astrophysical community using the LAT-MW mailing-list¹. Furthermore

¹Sign up for "gammamw" mailing list at address: <http://fermi.gsfc.nasa.gov/ssc/library/newsletter/>

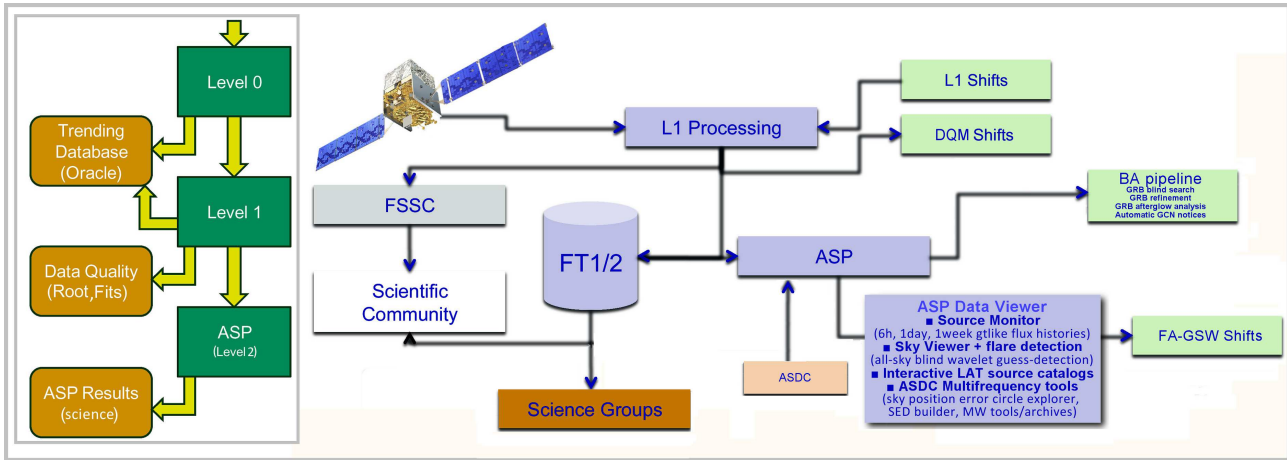


Figure 2: *Left inset panel:* diagram of the main general blocks of the *Fermi* LAT data processing flow at ISOC (SLAC, Stanford University). The final astrophysical science data (FT1 and FT2 fits files) are sent to the Fermi Science Support Center (FSSC) of the NASA Goddard Space Flight Center for public distribution to the scientific community. *Main panel:* block diagram of *Fermi* LAT data processing with final steps of duty services covered by members of the LAT collaboration in evidence (L1, Data Quality Monitor, DQM, Flare Advocate Gamma-ray Sky Watcher FA-GSW, weekly shifts). In particular the Automated Science Processing (ASP, Level 2 processing) is outlined with the links to the GRB automatic analysis pipeline and to the FA-GSW duty activity.

Astronomer's Telegrams (ATels)², automatic burst GCNs and special GCNs for blazar flares are distributed in addition to weekly summary reports in the "Fermi sky Blog"³ (Fig. 1). Thanks to this service joined with the public distribution of LAT data at the FSSC⁴ the *Fermi* LAT collaboration is therefore able to promote and increase the rate of multifrequency collaborations and observations, maximizing the scientific return and rate of international scientific cooperation of the *Fermi* mission. First seeds for variability and MW follow-up and studies are often triggered by the FA-GSW activity (see the LAT MW Coordinating Group⁵ and Thompson, D. J. [2009]).

2. ASP infrastructure

This activity is based on the automated quicklook data analysis of Level 2 (L2) at the *Fermi* LAT Instrument Science Operation Center (ISOC) of SLAC-Stanford (Fig. 2). L2 processing (instrument monitoring pipeline, background monitoring, and quick look science analysis) is triggered by the first availability of Level 1 (L1) processed data and performed on longer time intervals (six hour, 1 day and 1 week) referred therefore as Automated Science Processing

(ASP). The ASP analysis pipeline running on the final astrophysical science data (photon event files FT1, and spacecraft data files FT2 fits files) is composed of several scientific tasks (Fig. 2, and Cameron [2007], Chiang [2007]):

- automatic analysis of gamma-ray bursts (impulsive transients) through refinement of parameters for LAT-detected GRBs, detection and characterization of GRBs not detected onboard, search and analysis of delayed high-energy afterglow emission;
- flux history monitoring based on maximum-likelihood method (gtlike science tool) of prede-

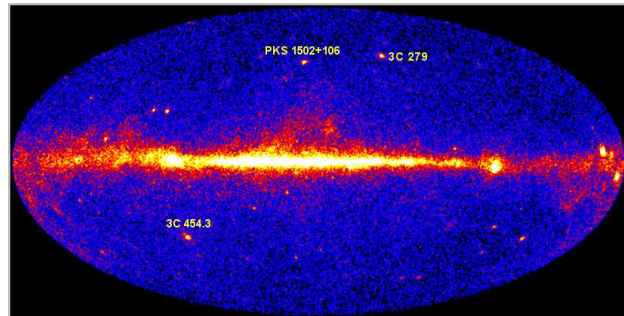


Figure 3: The all-sky photon count map above 100 MeV accumulated in one week of *Fermi* LAT survey. All-sky maps like this and automatic quick-look source detections are investigated on 1-day and 6-hour time intervals day by day by Flare Advocates. 3 bright blazars of the week are labeled (3C 454.3, PKS 1502+106, 3C 279).

²Web address: <http://www.astronomerstelegram.org>

³Web address: <http://fermisky.blogspot.com>

⁴Web address: <http://fermi.gsfc.nasa.gov/ssc/>

⁵Web address: <https://confluence.slac.stanford.edu/x/YQW>

Table I The 159 ATels posted divided for topics.

ATel type	Num.
Total Fermi ATels (on blazars mostly)	159
Fermi on Galactic sources	18
Fermi on the Sun	3
Swift results on ToOs triggered by Fermi	18
Fermi-Swift joined results	1
Fermi-Integral joined results	1
Fermi-WEBT joined results	1
Fermi-HESS joined results	1

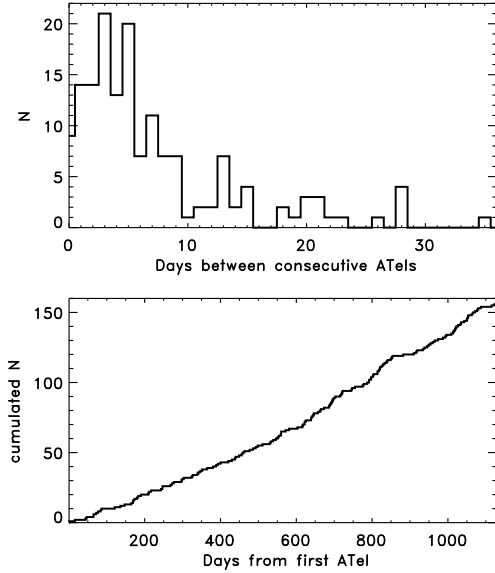


Figure 4: Distributions of the 159 Astronomical Telegrams (ATels) published on behalf of the Fermi LAT Collaboration from July 24, 2008 (ATel#1628) to August 24, 2011 (ATel#3580), i.e. in about 3 years of *Fermi* all-sky survey mission.

finer list of sources (called Data Release Plan, DRP, sources) with subsequent additions of publicly announced sources (like flaring blazars subject of ATels);

- blind guess-detection on all-sky photon counts maps accumulated in 6-hours, 1-day, 1-week intervals, through a fast method based on two-dimensional Mexican Hat wavelet transform, thresholding and sliding cell algorithms [Ciprini et al. 2007];
- transient and flare identification based on variability test;
- interactive LAT source catalogs;
- Multi-mission/multifrequency tools and archives (like the error circle explorer and the spectral energy distribution builder) linked

to ASP and provided by the ASI Science Data Center (ASDC, Roma)⁶.

3. Some results

The role and activity of the FA-GSWs is therefore twofold.

- Gamma-ray Flare Advocate task. Flaring sources approaching a daily flux of 10^{-6} photons $\text{cm}^{-2} \text{s}^{-1}$ deserves attention (detection, localization, flux, photon index checked, photon counts maps and exposure maps are outlooked). Internal/public notes, ATels, Target of Opportunity (ToO) are submitted, MW observing campaigns are organized when needed.

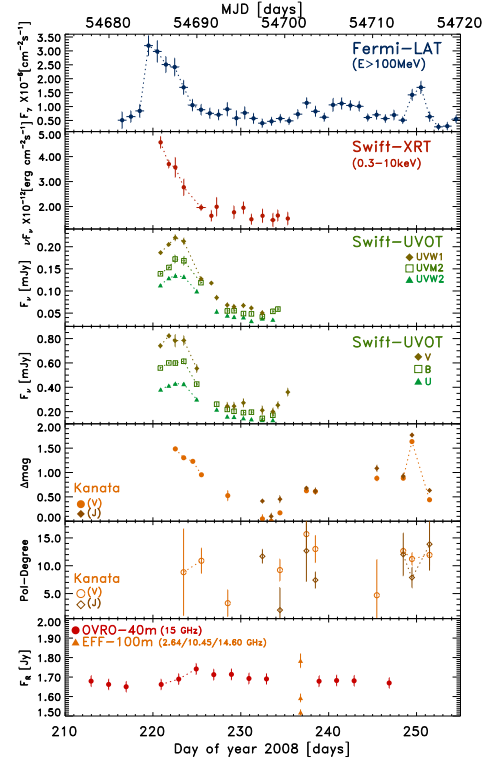


Figure 5: Simultaneous γ -ray and multifrequency light curves of the newly discovered γ -ray blazar PKS 1502+106 obtained during the MW campaign triggered by the outburst detected by *Fermi* LAT. Data reported in the panels are from *Fermi*-LAT (flux above 100 MeV), *Swift*-XRT (0.3-10keV flux), *Swift*-UVOT (six-band optical-UV fluxes), Kanata-TRISPEC (optical-near-IR differential magnitude ΔV and ΔJ bands and linear polarization), and OVRO 40m (15 GHz flux). Adapted from Abdo et al. [2010b].

⁶Web address: <http://fermi.asdc.asi.it>

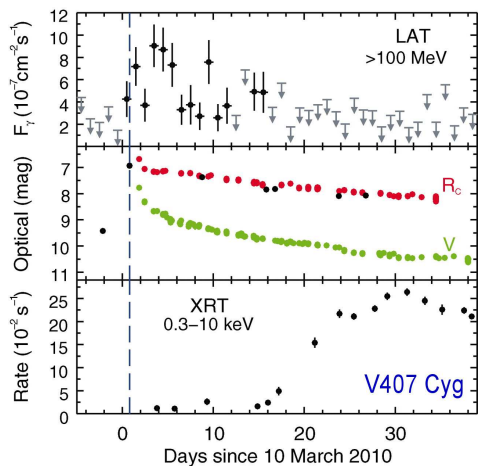


Figure 6: Light curves of V407 Cyg in γ -rays from the Fermi-LAT (top), optical (middle), and X-rays from Swift (bottom). Adapted from Abdo et al. [2010a].

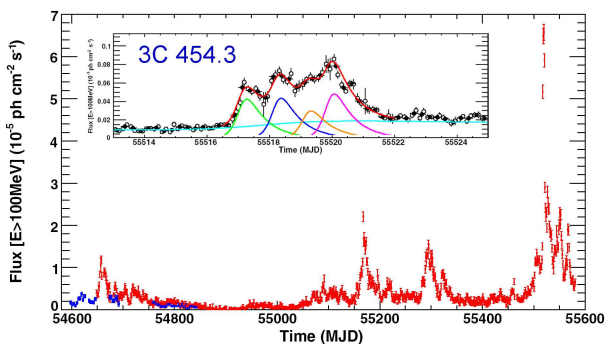


Figure 7: Main panel daily light curve of 3C454.3 measured with the Fermi-LAT since launch. Inset panel: Light curve of the flux above 100 MeV. Open and filled symbols are 3 hr and 6 hr averaged fluxes. Five component fit (sub-flares) is outlined. Adapted from Abdo et al. [2011].

- Gamma-ray Sky Watcher task. Results from the LAT Automated Science Processing (ASP) pipeline in 1-day and 6-hour time intervals are checked, searching for transients, increasing/decreasing brightness trends, and new γ -ray source candidates and spatial associations.

FA-GSWs discovered new gamma-ray blazars before the release of *Fermi* Catalogs, discovered several bright flares and outbursts from blazars, some transient from low galactic latitude source, observed the emission of the quiet-sun and the flaring-sun emission. In multifrequency science FA-GSWs triggered several targets of opportunity (ToOs) with the *Swift* satellite (about a dozen per year) and involved the radio-astronomy community in joint observing programs. MW observing campaigns on several blazar and galactic source targets were also performed.

In Table I and Fig.4 basic statistics about the 159 Astronomical Telegrams (ATels) published on behalf

of the Fermi LAT Collaboration from July 24, 2008 (ATel#1628) to August 24, 2011 (ATel#3580) are illustrated. The average rate of published ATels is about one per week/shift.

More in detail the substantial menu of discoveries triggered by the FA-GSW service is: many flares from γ -ray blazars (the extraordinary outbursts of 3C 454.3 Fig. 7 and Abdo et al. [2011] large flares of PKS 1510-089, 4C 21.35, PKS 1830-211, AO 0235+164, PKS 1502+106, Fig. 5, 3C 279, 3C 273, PKS 1622-253, 3C 66A, etc.); short/long activity duty cycles of bright γ -ray blazars; unidentified transients near the Galactic plane (like J0910-5041, J0109+6134, Galactic center region) or associated to Galactic sources (like the Crab nebula, the nova V407 Cyg Fig. 6 and Abdo et al. [2010a], the microquasar Cyg X-3, the binary star system 1FGL J1018.6-5856), intense MeV emission from the quiet and active sun.

The all-sky variability monitor of *Fermi* and the continuous day-by-day service performed by FA-GSWs represents the liaison between the Fermi LAT Collaboration and the MW astrophysical/astroparticle community, always invited to observe Fermi LAT sources and to propose MW collaborations.

Acknowledgments

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